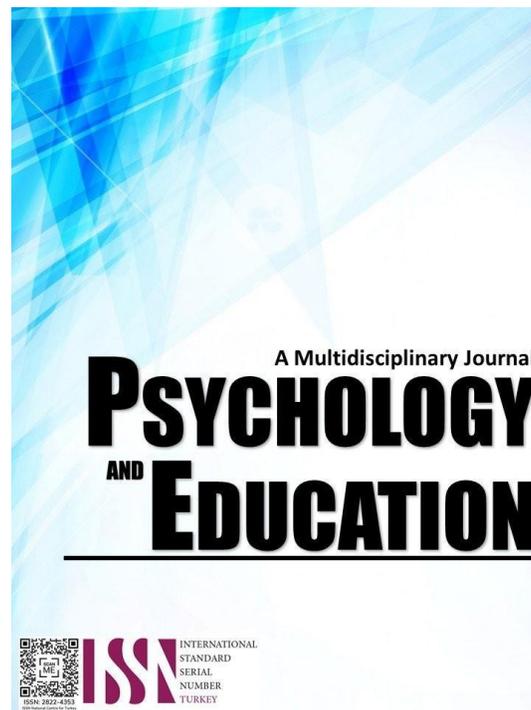


DIVERSITY AND ECOLOGICAL STATUS OF BRYOPHYTES IN SENATOR NINOY AQUINO, SULTAN KUDARAT



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Diversity and Ecological Status of Bryophytes in Senator Ninoy Aquino, Sultan Kudarat

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Abstract

Bryophytes are nonvascular plants that comprise mosses, liverworts, and hornworts. The current study evaluates the diversity and ecological state of bryophytes in Senator Ninoy Aquino, Sultan Kudarat. Three sampling sites were established based on the vegetation type of the area. Assessment of the bryophytes was done through opportunistic sampling. A total of twenty-one (21) species of bryophytes were identified, seven (7) mosses and twelve (12) liverworts belonging to twelve (12) genera and seventeen (17) families in the entire sampling area. Decayed logs, three trunks, wet rocks, rocks, and moist soil were observed as microhabitats. A high diversity index of 2.4959 with evenness of 0.8198 was observed in site 2. Site 2 is located at the highest elevation (664.72 m asl) recorded during the sampling. Bryophytes diversity increased with altitude. Although the site 1 elevation (610.78 m asl) is recorded as the lowest. The area is near the river, which can be the reason for the findings. Another factor that affects diversity is the disturbance level. Where the increasing diversity pattern of bryophytes was associated with an increasing level of disturbance. One (1) species (*Breutelia arundinifolia* [Dudy] Fleish) was found endangered, while others are widespread based on IUCN status.

Keywords: *bryophytes, diversity, diversity pattern, abundance, species*

Introduction

The diversity of bryophytes is not consistently dispersed in forested areas. Where, in fact, species richness is connected with diversity and management. Bryophytes are nonvascular plants that are small, green, simple, and spore-bearing. They are unique among land plants in that they have relatively large, perennial, photosynthetic, and free-living haploid gametophytes and unbranched diploid sporophytes that remain attached to the maternal gametophyte throughout their life cycle, making them heteromorphic (Shaw & Beer, 1999). It has estimates of 25,000 species, comprises of mosses, liverworts, and hornworts, which is, according to the European Red list (2021), 22.5% of bryophytes species are considered threatened, while in Philippines there are 1,200 species that has been reported, wherein according to, Fernando, et.al (2008), two species of bryophytes are recorded as the threatened plant. An early comprehensive attempt in studying the bryophytes present in UP, Diliman of Angeles et al. (2020) recorded nine mosses and two liverworts with a total of eleven identified bryophytes.

Factors such as humidity and temperature would affect the growth of bryophytes, in which the elevation of the location could affect the temperature, and high humidity conditions would provide more water for the bryophytes (Sidiq, 2019). Bryophytes are a group of plants that are moisture-loving and capable of growing in a wide range of habitats; they fluctuate in terms of their structural characteristics (Azuelo et al., 2010). Bryophytes play a significant role in the ecosystem, for example, as an air pollution biological indicator because they are prone to environmental changes, and soil contamination because some bryophytes flourish in high pH areas. Also, species such as *Mielichhoferia elongata* and *M. mielichhoferia* could grow in areas where copper is high. Likewise, some bryophytes species can be used as models for research, wherein a few bryophytes species can be used as herbal medicine, horticulture, and participate in mineral cycling. Furthermore, invertebrates rely on bryophytes for food and habitat (Russell, 1979; Shevock, 2001; Azuelo et al., 2010).

Municipality of Senator Ninoy Aquino is known for its abundant and diverse ecosystem, where it has been a habitat of numerous species, likewise, it has an estimated elevation above sea level of 2,209.4 ft... In the past few years, deforestation in Senator Ninoy Aquino has been increasing, according to Global Forest Watch. In 2020, it lost 57.1 ha of natural forest, leading to a decrease in diversity. Barangay Kuden, barangay Nati and barangay Tinalon is one of the rich barangays in SNA it comes of forested areas, where, vegetation throughout its range is diverse, it comes of different plants species which it reflects the diversity of bryophytes. Currently, there are still no studies that establish the diversity of bryophytes found in the Municipality of Senator Ninoy Aquino. Also, due to constant human activities of clearing, some areas are being disturbed and converted into agricultural land. Maybe it needs certain conservation status measures, due to the disturbance caused by such activities.

Presently, the knowledge of the bryophytes taxa in the Philippines is still lacking, particularly in unexplored areas like the Municipality of Senator Ninoy Aquino. Where, in fact, as observed, the Philippines' groves, marshes, etc., seem to be ecologically disturbed and converted into agricultural or tourist destinations. Thus, this study may contribute to the knowledge of the bryophytes present in Senator Ninoy Aquino. Also, enlightened the current conditions of bryophytes and may have contributed to the development of the conservation strategy of the bryophyte flora. Likewise, this study provided a better understanding of the current conditions and importance of bryophytes in the ecosystem.

Research Objectives

Generally, the study assessed the diversity and ecological status of Bryophytes in the Municipality of Senator Ninoy Aquino, Sultan

Kudarat. Specifically, the study aimed to:

1. Identify, classify, and describe the Bryophyte species in the Municipality of Senator Ninoy Aquino.
2. Recognize the ecological status of bryophyte species as: Rare, Widespread, Endemic, and Endangered.
3. Determine the diversity of Bryophytes in the Municipality of Senator Ninoy Aquino.

Literature Review

Bryophytes

In the study of Hernández et al. (2019), it was found out that the number of species doesn't fluctuate between studied sites, but the pattern of species diversity fluctuates between the three different slope. Species life composition in the elevational slope shows a clear response to disturbance of communities. Where human influence has significantly altered the elevation pattern of variety, and these changes depending on the ecological and taxonomic group studied.

According to IUCN (2019), numerous European mosses, liverworts and hornworts, are been in red list conservation status, according to IUCN's Guidelines for Application of IUCN Red List Criteria at Regional Level. The first thorough, region-wide study of bryophytes, identifies species that are on the verge of extinction throughout Europe. In total, 22.5% of bryophyte species studied are threatened, where two species considered extinct and six considered regionally extinct (RE). Furthermore, Near Threatened species account for 9.6% (173 species), whereas Least Concern species account for 63.5% (1,140 species). 93 species (5.3%) were categorized as Data Deficient (DD) because there was inadequate information to determine their risk of extinction. Climate change, Agriculture, Natural system modification and aquaculture were identified as the primary threats.

Understanding moss diversity patterns and community structures can help integrate nature conservation at several biota levels. In the study of Jiang et al. (2018), it was found out that bidirectional cluster analysis determined that there is an environmental gradient between the forest's border and its interior. Moss diversity changed greatly over the gradient from the outside to the inside. From the forest's borders to the country's interior, the range and median of morphological and functional variability decreased substantially. The multi-response permutation method indicated significant changes in species arrangement between the forest's borders and interior, as well as between the forest's middle and transects. At the forest's border, seven species with important values for indicating environmental conditions were discovered, but only one of these species was detected as an indicator of intermediate transect. Result, show that the patterns of species composition and functional diversity have significant marginal effects, and that the edges of the forest are marginal habitats with high biodiversity

As stated by Angeles et al. (2020), a total of 11 species of bryophytes, including 9 types of moss and 2 types of liverwort are being identified. *Hyophila invuta* (Hook.) A. Jaeger and *Taxithelium instratum* (Brid.) Broth, broadly scattered throughout the site. Meanwhile, *Meiothecium microcarpum*, *Cyathodium foetidissimum* Schiffn. and *Vesicularia montagnei* (Bel.) was rare. In comparison to earlier studies conducted at high altitudes and in humid settings, the species composition is very limited. Some causes, were persistent to disturbance and the existence of particular tree species, may influence the structure of bryophytes on the Diliman University campus in the Philippines.

Membreve et al. (2019) studied assessing the range and ecological status of the bryophyte flora in Kalikasan Park, Albay. From all sampling areas, a total of 8 species were gathered, comprising 5 moss and 3 liverwort species. During the study period, decomposing woods, tree trunks, moist rocks, and moist soil were observed as microbiological habitats. The research region had a high index value (2.29) and a uniformity index of 0.996. Trees have a much higher index than bryophytes located in the fern zone. Among those identified species, two are likely endangered and one is found to be endangered by IUCN status. In addition, three bryophytes discovered in the area have been determined to have therapeutic use.

Alcala (2019) stated that moss is one of the key elements of ecosystem diversity. Overall, 77 moss species were discovered in sampling sites constructed, with 43 and 48 species moving from Mt. Makiling and Mt. Sipit, respectively. The lower the altitude, the lower the biodiversity, which can be explained by the higher degree of turbulence. Furthermore, as altitude increases, so do species abundance, and variety. Higher temperatures, on the other hand, reduce species abundance and variety. Higher elevations on both routes improve moss diversity overall. A correlation analysis of moss species structure at the two sampling sites supports this, but diversity is dramatically reduced in sample plots located at 600 m. a.s.l at 900 m a.s.l and Sipit Trail at 800 m. a.s.l, as well as 1,000 m a.s.l (Makiling Trail) could be caused by canopy gaps or site disturbances. The results show that moss can be used as an indicator of the effects of climate change reasons to its responsiveness to ecological fluctuations.

Importance of Bryophytes

Saxene and Harinder (2004) stated that, despite the fact that bryophytes are among the oldest land plants, most people are unaware of their utility. Bryophytes are crucial for the environment and can be used in pharmaceutical items, horticulture, and domestic products. The numerous uses of the bryophytes progressively recognized around the world, where its potential bio mapping of atmosphere precipitation is also vast.

Mosses and liverworts have been discovered to be effective environmental indicators. Some bryophytes species only thrive in a narrow pH range, and their occurrence could benefit to predict soil pH; for example, *Merceya*, *Mielichhoferia elongata*, and *M. mielichhoferia* grow in copper-rich soil. Aquatic bryophytes also a good indicators of freshwater pollution, where in *Fontinalis*

antipyretica and *Platyhypnidium riparioides* are usually used as bio monitors for river quality evaluation (Gecheva & Yurukova, 2013). Govindaparyari et al. (2010) stated that the decrease and extinction of bryophyte populations, particularly epiphytes, is mostly driven by air pollution caused by gaseous and particle contaminants. Because they are easier to handle and have a far broader range of specific sensitivity and obvious symptoms to pollution than higher plants, bryophytes are reliable air pollution indicators and monitors. According to Liu (2021), *B. atrovirens* had a tough capacity to gather manganese with the cumulants of 5588.00 µg/g and 4283.41 µg/g, and some moss found in the manganese excess residua zones had a resilient enhancement of Cd.

Because of their trample-resistant architecture and regeneration capacities, moss species such as *Atrichum*, *Pogonatum*, *Trematodon*, *Pohlia*, *Nardia*, and

Blasia show an important part as soil corrosion inhibitors. *Rhodobryum* and *Dicranum* are *Acrocarpus* mosses that cover exposed substrata with netted and webbed protonemata and gametophores and increase the soil's water-holding capacity. Thus, bryophytes play a vital function in mineral retention where they trap any kind of nutrients that are dissolved in the rain, or leached from the soil, where living bryophytes will use the trap nutrients and later on, decaying bryophytes releases the nutrients to near plants. Also mosses can easily gather K, Ca and Mg from rainfall. Some mosses and liverworts are also responsible in nitrogen fixation in arctic and sub-arctic ecosystem.

Sphagnum moss, also known as peat moss, is an efficient purifying and absorption cause for the usage of factory excess water and discharge including heavy metals (Ag, Cu, Cd, Hg, Fe, Sb, and Ph), as well as organic compounds such as oils, detergents, dyes, and microorganisms. Also peat moss is an effective oil spills absorption (Saxena & Harnder, 2004).

Furthermore, bryophytes play a variety of roles in the environment, one of which is to filter nutrients present in the soil where it mats. It has great capacity to stabilize soil, where it has an effective soil binder and nutrient trapper. Lichens and bryophytes have root-like appendages that aid in soil binding, while biological soil crusts act as a physical barrier between rains and soil (Lepp, 2008). It indicates that the raindrops force will be absorbed by the crust, where it could lessen the potential erosion. Also bryophytes have a high water holding capacity to tolerate desiccation, where genus *Sphagnum* has 20 to 30 times holding capacity of water. Likewise, it forms a moist wet ground where it is beneficial to the seedlings to grow (Gairola et al., 2014).

Finally, bryophytes provide food, shelter, and material for nesting for small animals. Several invertebrates consume bryophytes, lay eggs on them, and use them as a refuge. The Southern Corroboree Frog (*Pseudophryne corroboree*) and Northern Corroboree Frog (*Pseudophryne pengillyi*) are found near *Sphagnum* bogs in south-east Australia (Lepp, 2008). This type of frog has been observed in *Sphagnum* bogs in the alpine and sub-alpine zones of NSW and the ACT.

Medicinal Uses of Bryophytes

As Chandra et al. (2017) stated, bryophytes are tool by various ethnic groups in Africa, America, Europe, Poland, Argentina, Australia, New Zealand, Turkey, Japan, Taiwan, Pakistan, China, Nepal, and various parts of South, North, and Eastern India to treat hepatic disorders, skin diseases, cardiovascular diseases, antipyretic, antimicrobial, wound healing, and many other ailments. Aside from ethno-medicinal use, few bryophytes have anticancer activity versus various cancer cell lines.

Chinese and native Americans crushed and created a paste of several moss species, including *Philonotis*, *Bryum*, and *Mnium*, before using it as a poultice. Burned moss motley with fat and honey and used as an ointment wounds, cuts and burns in India's Himalayan region. *Riccia* species rosette is an external application help to treat ringworm. An juice of *Rhodobryum giganteum* could improve aorta blood transit up to 30% in animals. Transgenic *Physcomitrella* is presently were used to create 'blood-clotting factor IX' in handling of 'haemophilia' B. Calcined peat treatments have been thought to be efficacious and low-cost disinfectants; peat water holds tough and antibacterial possessions. 'Sphagnol,' a Peat Tar distillation, is excellent for treating eczema, psoriasis, pruritus, hemorrhoids, chilblains, scabies, acne, and other skin problems, as well as relieving discomfort caused by insect bites (Saxena & Harnder, 2004).

Broad-spectrum antibiotics are produced by bryophyte species (Asakawa 2007a, b, 2008; Asakawa et al. 2013; Glime, 2017). According to Banerjee and Sen (1997), the moss *Brachythecium procumbens*, as well as the liverworts *Asterella sanguinea* and *Marchantia paleacea*, have the largest spectrum of antibiotic activity. Antibiotically active compounds have also been discovered in the moss genera *Atrichum*, *Dicranum*, *Minium*, *Polytrichum*, and *Sphagnum*. Petroleum-ether extracts of *Barbula* and *Timmiella* species, on the other hand, were found to be efficacious against both gram-positive and gram-negative bacteria. *Botrytis cinerea*, *Rhizoctonia solani*, and *Pythium debaryanum* were found to be inhibited by *H. aduncus* methanol extract. While, *Barbula* and *Timmiella* extracts were found to be effective against both gram-positive and gram-negative bacteria. *Plagiochila stevensoniana* reduced the growth of *Trichophyton mentagrophytes*, *Candida albicans*, and *Bacillus subtilis* (Saxena & Harnder, 2004).

The number of species doesn't fluctuate among studied plots, but the pattern of species ranges fluctuates between the three different slopes, and species life structure along the elevation slope shows a strong reaction to destruction of developed groups (Hernández et al. 2019).

According to the IUCN (2019), various species of mosses, liverworts, and hornworts have red list conservation status, based on the IUCN's Guidelines for the Application of IUCN Red List Criteria at the Regional Level. The first thorough, region-wide study of bryophytes, classifies species that are on the verge of extinction throughout Europe.

Understanding moss diversity patterns and community structures can help integrate nature conservation at several biota levels. Jiang, et al. (2018), found out that bidirectional cluster analysis determined that there is an environmental gradient between the forest's border and its interior. Alcalá (2019) stated that moss is one of the key elements of ecosystem diversity.

The lower the altitude, the lower the biodiversity, which can be explained by the higher degree of turbulence. Moreover, as altitude increases, species abundance increase. Higher temperatures, on the other hand, reduce species abundance, and variety.

Bryophytes play several roles in the environment, one of which is to filter nutrients present in the soil where it mats. It has a high capacity for soil stabilization, acting as a soil binder and nutrient trapper. According to Saxena and Harinder (2004), despite the fact that bryophytes are among the oldest terrestrial plants, most people are unaware of their utility. Bryophytes have applications in pharmaceuticals, horticulture, and domestic items, as well as being environmentally beneficial.

According to Chandra et al. (2017), bryophytes helps to treat hepatic illnesses, skin diseases, cardiovascular ailments, and as an antipyretic, antibacterial, and wound healing agent. Several moss species, including *Philonotis*, *Bryum*, and *Mnium*, were crushed and made into a cream before being directed as a dressing by Chinese and native Americans.

Methodology

Research Design

A descriptive-quantitative research design was used in this study to determine the diversity and ecological status of bryophytes.

Location of the Study

The research site was located within the ancestral domain of Barangay Kuden, Barangay Nati and Barangay Tinalon, Senator Ninoy Aquino, Sultan Kudarat. Barangay Kuden, Barangay Nati, and Barangay Tinalon were selected because they rise at 2,655.5 feet, 2,323.5 feet, and 2,960.3 feet, respectively, above sea level, and it has the most forest coverage area.

Sampling Method

Each location's bryophyte assessment was carried out via opportunistic sampling. This was accomplished by cataloguing all of the bryophyte species spotted and collected along the walk in various substrates (rock, trees, and ground). The trail was established according to the vegetation types in the chosen area.

Identification, Classification, and Description of Bryophyte Species

Using physical characteristics such as leaf arrangement, stem structure, habitat, and rhizoids, bryophyte species were identified, categorized, and characterized (Yamaguchi, 1993). In order to identify bryophytes, current herbaria and keys from books, scholarly articles, and journals were used. Microscopy was used for additional testing. One of the experts from Central Mindanao University, a bryologist, identified and confirmed the collected bryophytes.

Collection and Preparation of Herbarium Specimens

The collected bryophytes (mosses, liverworts, and hornworts) were placed in a paper pocket with the following data: altitude, collection number, date of collection, ecology, and associated habitat. Fresh specimens were pressed, air dried, and packed in an envelope with the appropriate label.

Assessment of Conservation Status of Bryophyte Species

The conservation status of bryophyte species was revealed as rare, widespread, endemic, and endangered. This was evaluated using the International Union for Conservation of Nature (IUCN) literature base, as well as scientific journals and website searches.

Data Analysis

The diversity index of bryophyte species was determined using BioPro ver.2 (Biodiversity Professional). This statistical method is useful for quantifying byrofloral species variety, such as relative abundance.

Ethical Considerations

A clearance from the National Commission of Indigenous Peoples (NCIP), Department of Environment and Natural Resources (DENR), and prior to the study, clearance from designated barangays was secured. This is to ensure that the governed laws on AO-2004-5T were followed.

Results and Discussion

Senator Ninoy Aquino Vegetation Type

Senator Ninoy Aquino is a landlocked municipality in the coastal province of Sultan Kudarat. The municipality had 11.0kha of natural forest as of 2010, which holds over 35% of the total land area. A variety of different vascular and nonvascular plants exist in diverse habitats (Global Forest Watch).

Barangay Nati (site 1), Barangay Tinalon (site 2), and Barangay Kuden (site 3) are situated in the northeast area of the municipality. The forest was characterized by mixed small and tall trees. The slope was considerably less steep in site 3 compared to sites 1 and 2. With the elevation of 610.78 m asl, 664.72 m asl, and 633.50 m asl, respectively.

Taxonomy

Table 1. List of Bryophytes in Senator Ninoy Aquino

Family	Species	Site 1	Site 2	Site 3
Bartramiaceae	<i>Breutelia arundinifolia</i> (Duby) Fleisch	+	+	
Conocephalaceae	<i>Conocephalum conicum</i>	+	+	+
Calymperaceae	<i>Syrrophodon tristichus</i> Nees ex	+	+	
	Schwager			
Lepidoziaceae	<i>Bazzania trilobata</i>	+	+	
Leucolejeunea	Species 1		+	
Lophocoleaceae	<i>Lophocolea bidentate</i>	+	+	+
Monocleaceae	<i>Monoclea gottshei</i> Lindb.	+	+	+
Marchantiaceae	<i>Marchantia polymorpha</i>	+		
	Species 2	+		
	Species 3	+		
	Species 4	+		
Pallaviciniaceae	<i>Symphogyna brongniatii</i> Mont.	+	+	+
	<i>Symphogyna</i> sp	+	+	+
Polytrichaceae	<i>Pogonatum macrophyllum</i> Dozy &	+		
	Molk			
Porella	Species 5	+	+	
Prionodontaceae	<i>Prionodon fuscoletesscen</i> Humpe		+	
Racopilaceae	<i>Racopilum johannis-winkleri</i> Broth	+	+	
Rhizogoniaceae	Species 6		+	+
Scapaniaceae	<i>Scapania</i> sp		+	
Schistochilaceae	<i>Schistochila</i> sp	+	+	+
	Unidentified		+	

The study revealed 21 total bryophytes species, eight (8) species of mosses, and twelve (12) species of liverworts. The specimens were identified and classified; several bryophyte species were described based on the bryophyte taxonomic treatments, including the habitat, leaf arrangement, stem structure, and rhizoids.

Breutelia arundinifolia (Duby) Fleisch.

Description: Yellowish green, glossy, stems erect, multibranched, leaves ovatelanceolate, longitudinally plicate, narrowed, auriculate at base.

Habitat: Wet rocks

ES: Endangered

Conocephalum conicum

Description: Dark green, leathery surface, flat and smooth, air pores could be found between the lines.

Habitat: Rocks

ES: Widespread

Bazzania trilobata

Description: Glossy green, leafy, incubous leaf-overlap pattern, trilobed leaf-tips.

Habitat: Rotten tree, Tree trunk

ES: Not Evaluated

Lophocolea bidentate

Description: Translucent, pale green in colour, bilobed leaves.

Habitat: Rotten tree trunk

ES: Widespread

Monoclea gottshei Lindb.

Description: Leaves margins irregular and obtusely crenate-cristae.

Habitat: Rocks

ES: Widespread

Marchanta polymorpha

Description: Yellowish, flat, branching form, numerous rhizoids attach the thallus to the soil.

Habitat: Soil

ES: Widespread

Porella sp

Description: Yellowish green, having lobed leaves that have a wide upper lobe and a short lower lobe, stem pinnately branched with leaves. Rhizoids arise from the base of leaves.

Habitat: Tree trunk

ES: Widespread

Family Rhizogoniaceae

Description: Leaves and branches similar in form; bilaterally symmetrical; lanceolate; spiral. Stem erect, much branched.

Habitat: Tree trunk

ES: Widespread



Figure 1. Documented Bryophytes (A. *Marchantia polymorpha*, B. *Lophocolea bidentate*, C. *Conocephalum conicum*, D. *Monoclea gottshei* Lindb., E. Mniaceae sp, F. *Leucolejeunea* sp, G. *Breutelia arundinifolia* (Dudy) Fleish, H. *Schistochila* sp, and I. *Pogonatum macrophyllum* Dozy & Molk) found in Senator Ninoy Aquino.

Species Richness

The three sampling sites revealed 21 bryophyte species belonging to 12 genera and 17 families. In which the family of *Marchantiaceae*, *Mniaceae*, and *Pallaviciniaceae* (2 spp.) are the most represented species of bryophytes in the area. Among the identified bryophytes

species, 8 species of moss with 6 genera and 5 families were classified, and 12 liverworts belonging to 8 genera and 9 families. Although there were no hornworts collected. The mentioned bryophytes were generally seen along the trail from the starting point to the end point. While one bryophyte species remains unidentified.

Bryophytes Distribution and Diversity Indices

Bryophytes species were found diverse in site 1 and site 2, having sixteen (16 spp.) respectively of the total identified species, followed by site 3 (7 spp.). It was observed that high diversity of bryophytes would be seen at high elevation levels, and the disturbance level is low. Site 2 is located at the highest elevation (664.72 m asl) recorded during the sampling. Bryophytes diversity increased with altitude, as altitude increases, so does relative humidity (Myers et al. 2000; Alcalá, 2019). Habitats of liverworts and mosses were associated with altitude, which was associated with moisture and nutrients, but light and soil acidification were solely related to mosses (Chmura, Zarnowiec, & Staniaszek-Kik, 2022). Likewise, waterways could be seen in the site that may provide moisture in the area. Although the site 1 elevation (610.78 m asl) is recorded as the lowest. The area is near in the river, which can be the reason for the findings. Moisture is one of the factors that could affect the bryophytes' composition and diversity. Thus, the river provides moisture to the soil and the environment, hence moisture on the site is a driver of bryophyte assemblages (Bartels et al., 2018). Another factors that affect the diversity is the disturbance level. Where the increasing diversity pattern of bryophytes is associated with an increasing level of disturbance. Site 3 has coffee plantations and less slope compared to the two sites and is near the motorway and accessible, which is why the disturbance level is high. Whereas, site 1 and site 2 are more sloped and site 1 is distant from the road, although site 2 is near the national highway, the area is much preserved compared to site 3, which gives a favorable habitat for bryophytes. As disturbance intensity increased, plant species richness and soil fertility declined (Ren, 2021).

Bryophytes species are mostly epiphytic, growing on decayed logs, tree trunks, and wet rocks. Study revealed that fourteen (14) or 66.6% of bryophytes were found on trunks, decayed logs, and branches. Seven (7) or 33.3% were found in rock surfaces, and three (3) or 14.3% were found in soil. The huge species populations isolated to rotten woods served as substratum, supplying nutrient-rich resources to ancillary floras such as mosses and can boost the growth of all tiny plants (Bates, 2000).

Table 2. *Index of Diversity in Three Sampling Sites*

<i>Sampling Area</i>	<i>Shannon Index of Diversity</i>	<i>Shannon Index of Abundance</i>	<i>Pielou's Index of Evenness</i>
Site 1	2.4535	3.0445	0.8058
Site 2	2.4959	3.0445	0.8198
Site 3	1.8200	3.0445	0.5978

The total of 16 bryophyte species in Site 1 was recorded with a diversity value of 2.4535 and an evenness of 0.8058. Site 2 has a total of 16 species with a diversity value of 2.4959, 0.8189 evenness, and a total of 7 seven species recorded in site 3 with a diversity value of 1.8200, while the evenness is 0.5978. Measured diversity value and evenness index in the three sampling sites indicate a high diversity of bryophytes in site 2 and site 1. The high diversity value of sites 2 and 1 may be because they are covered with secondary forest, where the disturbance level is low. This gives a favorable habitat for bryophytes, while site 3 is inhabited by coffee plantations, and the disturbance level is high. It has an open canopy due to clearing, thus increasing the sunlight penetration and reducing the moisture. Therefore, the diversity of bryophytes decreases. The canopy of the forest is known to protect moisture-loving plants, bryophytes, from intense light and desiccation (Benitez, Prieto & Aragon, 2015; Hipol et al., 2007; Membreve, 2019). In addition, the moisture or water is important to the photosynthesis and growth of bryophytes (He, He and Hyvonen, 2016; Membreve, 2019).

Several factors might affect the diversity of bryophytes, as Sun et al. (2010) stated, climate, height, slope, litter depth, vegetation kinds, soil pH, and soil type all have an impact on the composition and variety of bryophytes. The species diversity per trail in different altitudinal gradients seemed to fluctuate upon reaching a high elevation. It is observed that a high diversity of bryophytes is situated at a high elevation level of the three (3) sampling sites (610.78 m asl, 633.50 m asl, and 696 m asl). In which site 2 and site 3 are located at a high elevation. Although site 3 is placed on a high elevation site, 3 is less diverse compared to site 1. This may be because of the geographical location and environment of the three sites, whereas in site 1, a river is present that could give moisture to the area, and the slope is slightly steep, which means the disturbance level is low. The composition of bryophytes is influenced by the type of vegetation and the ecological environment (Azuelo et al., 2016).

Bryophytes Conservation Status

Table 3. *Ecological Status of Bryophytes*

<i>Bryophytes</i>	<i>Rare</i>	<i>Widespread</i>	<i>Endemic</i>	<i>Endangered</i>
Mosses	0	6	0	1
Liverworts	0	11	0	0
Hornworts	0	0	0	0
Total	0	17	0	1

Evaluations of status of 21 species of bryophytes showed one species of moss, *Breutelia arundinifolia* (Dudy) Fleish is endangered although aside from its appearance, information about the species is lacking (Malaysian Biodiversity

Information System). While, moss, *Syrrhopodon tristichus* Nees ex Schwager, *Pogonatum macrophyllum* Dozy & Molk, *Prionodon fuscoletescen* Humpe and *Acopilum johannis-winkleri* Broth is widespread. Likewise, liverworts such as *Conocephalum conicum*, *Lophocolea bidentata*, *Monoclea gootshei* Lindb,

Marchantia polymorpha, *Symphogyna brongniatii* Mont., *Symphogyna* sp, *Scapania* sp and *Schistochila* sp is widespread based from the IUCN status. Thus, there is one species that is not yet assessed for its status.

Medicinal Value of Bryophytes

Some identified bryophytes have been found to be useful in medicine. In ancient times, bryophytes were used to cure cuts, swelling tissue, infections, and burns. The family Bartramiaceae is used to treat blisters and infections, while the genus *Bazzania* is used as an anti-carcinogenic and antimicrobial, and species such as *Conocephalum conicum* is a popular treatment for cuts, swelling tissue, burns, and fractures. *Marchantia polymorpha* is used for hepatic disorder, and *Pogonatum macrophyllum* Dozy and Molk are used as a diuretic, laxative, and hemostatic agent; it is used to treat inflammation, cancer, and fever (Bandyopadhyay & Dey, 2022).

Conclusions

Bryophytes are small, green, simple, spore-bearing plants that include mosses, liverworts, and hornworts, with an estimated 25,000 species worldwide. These plants are unique among land plants due to their non-vascular structure and reproduction via spores. This study assessed the diversity of bryophytes in Senator Ninoy Aquino through opportunistic sampling across three different sites. A total of 21 bryophyte species, belonging to 12 genera and 17 families, were identified. Shannon's index of diversity was calculated, yielding values of 2.45 for Site 1 and 2.59 for Site 2, indicating high diversity in these areas. Among the 21 species, one was found to be endangered, while 17 were categorized as widespread. Interestingly, the increasing diversity pattern appeared to correlate with higher levels of disturbance, suggesting bryophytes may thrive in moderately altered environments. Sites 1 and 2 were identified as the most diverse, each hosting 16 of the 21 recorded species. Based on the study's findings, several recommendations are proposed: (1) further research should be conducted in other parts of Senator Ninoy Aquino to expand and describe the existing list of species through additional collections; (2) since the assessment was carried out during the rainy season, a follow-up study during the dry season is recommended for comparison; and (3) immediate conservation actions and awareness programs should be implemented for the endangered species, especially about its potential ethnobotanical uses.

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